Fuel Supply Planning for Small-Scale Biomass Heating Systems

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ABSTRACT

The Fuels for Schools and Beyond initiative partners have gained experience assisting with installation and fuel supply planning for woody biomass heating systems in six western states. In attempting to use forest management waste or slash that would otherwise be piled and burned, the partners are promoting changes in currently available biomass systems technology and current forest practices. The many benefits of forest biomass heat can be realized today with careful communication about fuel supply specifications. Guidance based on the partners' experience in fuel supply planning and defining fuel specifications is presented.

Keywords: biomass supply assessment, biomass fuel production, biomass heat, biomass boiler fuel

Fuels for Schools and Beyond (FFSB) partners promote and facilitate the use of forest biomass for heat, electricity, and cooling in small- to medium-scale facilities. Our goals include replacing fossil fuels with renewable biomass, reducing greenhouse gas emissions, fostering local economic activity, lowering energy costs, reducing dependence on foreign fuels, reducing emissions from open burning, and using material that is often wasted. In Montana alone, about 1.5–2 million green tn of slash from forest management is burned in open piles annually (Brian Long, pers. comm., Montana Department of Natural Resources and Conservation [DNRC], 2007). Although proven technology exists for woody biomass heat and energy systems, they are uncommon in the United States, outside the industrial wood products sector. Most of the small-scale systems that are in place have historically relied on bole-wood waste from wood products manufacturers for fuel (Sherman 2007). The use of forest slash and other underutilized wood as fuel thus typically requires building a new energy sector, including local fuel production and distribution infrastructure. This article describes our approach toward that endeavor and provides guidance on fuel supply planning for woody biomass burning facilities.

Background

FFSB is a partnership between State and Private Forestry (S&PF) in the Northern and Intermountain Regions of the US Forest Service and six state foresters from Montana, Idaho, North Dakota, Nevada, Utah, and Wyoming. Another primary partner is the Bitter Root Resource Conservation and Development (RC&D) Area in Hamilton, Montana. Other RC&Ds, private businesses, and nonprofit organizations have assisted with projects also.

After the fire season of 2000, in which over 350,000 ac in the Bitterroot Valley burned, the US Forest Service began delivering funding under the National Fire Plan for hazardous fuels reduction, the use of woody biomass, and related needs. A local resident with interest in biomass heat researched existing systems in Scandinavia, Europe, and the northeastern United States. As a result, the Bitter Root RC&D, the US Forest Service's Forest Products Laboratory, Northern Region S&PF, and the nonprofit Biomass Energy Resource Center (BERC) partnered to fund a biomass heating system at three public schools in Darby, Montana (Bergman and Maker 2007).

When planning began, the fuel oil to be replaced by biomass cost less than one dollar per gallon, and the system was projected to save $30,000 per year on fuel (Bergman and Maker 2007). With fuel oil approaching four dollars per gallon, Darby's system saved nearly $150,000 during the 2007–08 school year (Rick Scheele, pers. comm., City of Darby, Montana and Darby School District, Jul. 9, 2008). As the benefits at Darby became clear, S&PF personnel in the Northern and Intermountain regions decided to expand the idea to the FFSB six-state initiative. FFSB partners have since become a national resource, providing advice in many states, implementing two national workshops, and speaking at regional and national events.

Fuel Supply Planning

Several questions must be answered when a biomass system is proposed. How much fuel will it take? Where will it come from? Is there enough fuel available on a sustainable basis? How will facilities acquire fuel? Who has equipment to process and deliver it? What will the fuel need to look like? How variable can it be? How much will it cost? This section describes factors to consider in fuel supply planning, including what information may be sought from public forestland managers, and from those who monitor management of private lands.

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Fuel Quantity

Fuel quantity and fuel quality considerations are presented separately in this section, but it is important to note that the two are interdependent. In considering fuel quantity two numbers are needed: how much fuel is required for the facility's energy needs and how much fuel is available within an economically feasible haul distance. The amount of fuel needed is determined via energy modeling during the design phase of a project. However, it can be estimated by averaging past annual fuel use records and calculating the number of British thermal units (Btu) required. Although heating values vary by species, on average, 1 tn of woody biomass at 40% moisture content provides 10.8 million Btu (BERC 2007). Estimates that account for the relative efficiency of the existing heating system and the proposed biomass system will be more accurate. It is best to consult with an engineer to determine the optimum boiler size, but, typically, it is most efficient to replace 90% fossil fuel use with biomass and to retain the existing system for backup and to meet the peak heat load (Stevenson 2007).

One advantage of small- to medium-scale biomass systems is that they can be fueled with local resources. Because woody biomass is low in density and typically has high water content (25–50% by weight), it is expensive to move (Morris 1999). When estimating available fuel quantities, it is helpful to define an economically feasible geographic area to draw from, recognizing that this varies depending on the price of fuels offset with biomass and the cost of processing and transporting biomass. Once a geographic boundary is determined, potential sources within that boundary can be investigated. The following section outlines one method for estimating locally available supply.

People are often surprised by how much biomass is being generated and how little is needed to heat a facility. A conservative estimate of biomass residues produced per acre of forest thinning in ponderosa pine/Douglas-fir forests is 10 tn at an average moisture content of 40% (this varies widely by forest type, stand conditions, and type of treatment). Darby's three public schools are heated for the entire school year with about 750 green tn, or the equivalent of waste generated from 40–80 ac (Bergman and Maker 2007). This is a small number when considering the many thousands of forested acres within an economically feasible haul distance for that area, about 80 road mi.

The sustainability of biomass removal is critical to the long-term success of a biomass project. Federal and state land-management agencies have guidelines indicating how much woody biomass should be left on a site for soil nutrients and structure, wildlife habitat, and other ecosystem functions. These recommendations evolve over time as scientists learn more about the effects of biomass removal, but, generally, slash burned in piles is considered to be in excess of ecosystem needs and is required to be treated to reduce the post-treatment fire hazard.

For example, the state of Montana has a hazard reduction law that requires treatment of slash created by forest management, either by piling and burning or removing the material from the site, within 18 months of the activity. The law's intent is to minimize the fire danger associated with slash left on the ground. By requiring this, the law ensures that slash treatment is included in the cost of forest management. Thus, some of the costs of using slash can offset required treatment costs, because instead of preparing slash for burning, it can be prepared for removal. For more information, visit www.dnrc.mt.gov/forestry/service forestry/timberslash/index.htm.

Estimating Available Fuel Supply

Montana Department of Natural Resources and Conservation's (DNRC) personnel have estimated available fuel supply for several biomass heating projects and assisted with fuel supply procurement. Our method for projecting fuel availability is to use the radius of assumed haul distance (typically 30–50 air miles as a proxy for 50–80 road miles) and gather information regarding planned and past forest management activity within that area.

Projected future production from public lands is estimated in the following manner. We contact federal and state forestland managers to learn what projects are proposed over the next 5–10 years, when each will be implemented, how much noncommercial volume each might generate, the road distance from each site to the boiler, how many miles are paved and unpaved, accessibility of the road system to chip vans and grinders, whether temporary roads or access restrictions are involved, and the stage of planning and public involvement for the project. We estimate the annual available biomass from public lands for as far forward in time as the information is accurate enough to be useful. In contrast to estimating growth and yield of forests in an area, this approach takes into account social and economic factors that may limit available biomass from public lands.

To estimate potential production from private lands, we use historical data on logs delivered to mills from private lands, which is collected under the state hazard reduction law. Based on an unpublished analysis by a US Forest Service employee, a factor of 0.87 tn of biomass per thousand board feet of delivered product is used to estimate the volume of recoverable biomass produced (Lee Harry, pers. comm., US Forest Service, Beaverhead-Deerlodge National Forest, Montana, Jan. 31, 2005). We calculate the annual tonnage produced within the projected delivery radius and generate 5- and 10-year averages to illustrate variability. At last, we collect information from wood products manufacturers, urban forest managers, and other waste producers, including the amount of biomass they produce, the moisture content, size range and other properties of that waste, and their current disposal method(s).

We then hold a prebid meeting with potential suppliers, whom we identify by contacting the Montana Logging Association, state and federal land managers, consulting foresters, and mill owners and operators. We share the information about potential supply sources and a draft of the fuel supply contract, making clear that bidders are responsible for securing supply and the information does not guarantee access to any specific product. We seek feedback on the draft contract and make adjustments before issuing a Request for Proposals. This approach tends to increase the level of competition, which helps the biomass end user.

Scales of Biomass Users

The method described previously is more effort than necessary for most small- to medium-scale biomass heating systems. Biomass users of varying scales are likely to be proposed as our nation works toward energy independence. This section provides examples of different woody biomass users and their feedstock needs.

The largest system in Montana FFSB is the University of Montana-Western in Dillon, which requires 3,500 tn of fuel per year. DNRC developed the aforementioned fuel supply method during planning for this facility. Because the campus is in a large, open valley, citizens were concerned about the distance to fuel sources and whether enough fuel would be locally available. DNRC's analysis showed that there was far more than enough fuel, which kept the project moving forward at a critical point in time.

Larger public biomass project examples include Nebraska's Chadron State College, which uses 8,000–10,000 tn/year, and the University of Idaho, which uses 40,000 tn/year, for heat, cooling, and energy generation (Coston 2005, Smith 2007). The largest biomass user in Montana is Smurfit-Stone Container Corporation in Frenchtown, a pulp mill that burns about 350,000 green tn of biomass per year to generate electricity for linerboard production (Rick Franke, staff comm., Smurfit Stone Container Corporation, Apr. 26, 2007).

Interest in producing cellulosic ethanol from woody biomass is also growing. One estimate is that a small commercial scale plant would require about 325,000 green tn/year to produce 25 million gal (Pennsylvania Department of Conservation and Natural Resources 2008). However, the scale of production required for economic viability is not yet certain, so producers might determine that they need to make 100 million gal/year to achieve an economy of scale, requiring four times the biomass. It is also possible that cellulosic ethanol producers will perfect a process that uses a variety of feedstock, in which case only a portion would be woody biomass. These examples illustrate the range of possible demands that may arise for woody biomass.

Fuel Quality

The importance of fuel quality and clear communication about fuel quality can not be overemphasized, particularly for smaller-scale systems (BERC 2007). Three aspects of fuel quality are important to establish for the boiler manufacturer and fuel supplier(s): size, moisture content, and fuel composition. Two main operations challenges are caused by lower quality fuel: fuel conveyance problems and "clinker" formation in which ash fuses and adheres to portions of the fire box or gasifier. Boiler manufacturers make many statements about their ability to handle different fuels. It is important to recognize that although manufacturers may be able to build different systems that will each successfully handle different types of fuel, it is likely not their intent to convey that all of their systems can handle the full variety of fuels without substantial operational challenges and costs. Therefore, it is advisable to share as much information as possible with manufacturers before a system is built, regarding the type of fuel and variation expected. Burning more consistent fuel involves less operations and maintenance time and difficulty (BERC 2007).

Fuel Size

Fuel size primarily impacts the performance of fuel conveyance equipment but can also interfere with the quality and completeness of combustion. The size of fuel pieces and variation in size are a function of how the fuel is produced. Grinders produce fuel by hammering pieces of wood apart, versus chippers, which cut with knives. Depending on the sharpness of knives and material fed into them, chippers produce more uniform pieces that are slick and easy to convey, while grinders produce fuzzy and stringy material that can bind together. Both production methods can have difficulty eliminating long sticks when processing whole tree material with limbs, because small diameter sticks can be forced through production without getting broken or cut.

For many biomass heating systems, the ideal fuel size is 2½ × 2½ × ½ in. or matchbook-sized chip. The range of variability in size that is acceptable varies, but in most cases, the maximum size allowable is a 6-in.-long stick no larger than a pencil in diameter, so that it will break as it travels through the conveyance system. In our experience, some systems routinely handle substantially larger pieces—roughly twice that size in all dimensions—without jamming the conveyance equipment. If a significant proportion of fuel consists of long sticks or stringy pieces, they can mat together or bridge, so no more than 5% should be of this type. In gasification systems that require tight airflow control, oversized pieces can jam the conveyance equipment in ways that allow excess air to enter the gasifier, resulting in higher than desired temperatures that cause clinker formation.

Fines or small fuel particles can also cause operations problems. Often, this is a function of fuel composition; a high proportion of fines typically indicates that there is substantial mineral content from needles, bark dust, and/or dirt. But all fuel processing methods produce some fines from woody material as well. Fines that are noncombustible or mineral based result in high ash content, and depending on combustion temperatures, may create clinkers, increasing operations and maintenance costs. Fines comprised of combustible material are sometimes difficult to completely combust because of the airflow in these systems, so a high proportion of woody fines can result in inefficiency by not recovering as much energy out of the fuel. Sometimes, if the airflow is not properly adjusted for the fuel type, partially combusted woody particles exit the stack and accumulate on the roof and around facilities. Visible char such as this is undesirable but is generally too large to create the negative health impacts that are associated with particulate matter smaller than 2.5 microns (PM 2.5), which is a regulated pollutant. However, all biomass system owners should be aware of the health effects of fine PM and seek to control its emissions through efficient operation, proper maintenance, dispersion, and appropriate air quality controls.

Moisture Content

Most manufacturers of biomass systems specify a wide range of acceptable moisture content, from 6% up to 45%, wet basis. Again, although systems can be adjusted to handle fuel of different moisture contents, high variability from load to load, or within a load of fuel will require more operations time. The lower the moisture content, the greater the net energy value of the fuel, because energy is required to drive off moisture. It is more efficient to transport fuel with lower moisture, because more of the transportation vehicle's weight is fuel rather than water, resulting in more Btu's per load. However, fuel of very low moisture can be difficult to completely combust, particularly when a high proportion of fines are present (BERC 2007). Most manufacturers specify an ideal moisture content range of 25–35%.

DNRC has helped establish fuel supply contracts with a sliding fee scale per ton for different moisture contents, to compensate the greater efficiency of drier material. We are evaluating this approach, but it appears that the accounting required may be more effort than warranted by the benefits when fuel demand is relatively small.

Fuel Composition

Fuel composition includes how much combustible and incombustible material is in the fuel, as well as the proportion of bolewood to needles and bark. Incombustible dirt, rocks, or debris create excessive wear on equipment and lead to clinkers. Clinkers occur when ash, which is made up of minerals, becomes hot enough to vitrify or fuse. When clinkers occur, it is often assumed that fuel is dirty.

Although dirt and rocks do cause clinkers, they can also result from a high proportion of needles and bark; needles contain about 20% mineral content, bark contains 5–7%, and bolewood contains less than 1%. Whole tree material therefore has higher potential for ash fusion than wood chips without bark or needles (BERC 2007).

Most written fuel contracts require fuel to be free of rocks, dirt, and other incombustible materials. In our experience, it is very difficult to eliminate all dirt and rocks from forest management waste. So, although FFSB facilities technically require none, they expect to encounter some rocks and dirt. We have not determined how much is acceptable, but because contracts state that no amount is acceptable, facilities have the advantage in working with suppliers when problematic levels of dirt or rocks occur. Similarly, because we have not determined what proportion of needles and bark is acceptable, our fuel specifications have not addressed this.

The wood products industry has used wood burning systems for decades that acceptably handle fuel with high mineral content. The round-the-clock operating environment and industrial scale of wood products facilities have made this economically feasible. In scaling biomass boiler equipment down to smaller settings, we have learned that features such as moving grates may be important in enabling the use of high mineral content fuel, and that these features will add to the up-front costs of biomass systems. Manufacturers are working toward creating affordable technology at the smaller scale to make our goal of using lower quality fuel more achievable. We are also working with land managers and fuel producers to encourage cleaner methods of fuel production.

Fuel Quality Summary

It is critical to the success of biomass heating projects that fuel specifications are evaluated, decided on, and clearly communicated in contracts with both the boiler manufacturer and the fuel supplier. Without specific direction otherwise, manufacturers will build systems for the ideal matchbook-sized bolewood chip. Boiler manufacturers can build systems to handle the desired fuel, but costs will be higher for equipment with wider fuel tolerances. For examples of fuel specifications and contracts visit www.fuelsforschools.info.

Agency Efforts to Improve Fuel Quantity and Quality

As mentioned previously, FFSB partners believe that widespread use of woody biomass heat/energy requires building a new energy sector. Because most slash is piled and burned, forest workers often regard it as having negative value (because of the cost of disposal). As our country works toward energy independence and biomass utilization becomes more common, this mindset will evolve. However, forest management agencies can accelerate change through policies that favor treating woody biomass as fuel rather than a waste product.

An example is occurring in the Northern Region of the US Forest Service. In early 2007, the Regional Forester directed timber management personnel to require in timber sale contracts that submerchantable wood at least 12 ft long and 3 in. or larger in diameter be delimbed and decked. Although they do not require the material be removed rather than burned, this policy typically results in removal, because it creates a clean and usable form of biomass, rather than a tangled pile of slash. This policy has increased utilization; in the first half of fiscal year 2008, removals of nonsawlog volume from Northern Region National Forests totaled just over 100,000 tn, compared with 120,000 tn removed in all of fiscal year 2007 (Jerry Thompson, pers. comm., US Forest Service, Northern Region, Apr. 4, 2008).

DNRC has also changed practices to encourage utilization by providing a preference for bidders who plan to use slash instead of burn it. The provision is optional, but once purchasers indicate planned utilization, they are required to follow through. DNRC plans to experiment with a policy similar to the Northern Region's on state trust lands and evaluate the costs and benefits to trustees of delimbing and removing submerchantable material (Robert Ethridge, pers. comm., Montana DNRC, Jun. 6, 2008). Whether it gets used for firewood, animal bedding, pellet manufacturing, or in a biomass heat/energy or biofuel plant, we feel the era of wasting this material should end. However, an important driver for these changes is whether enough of a market exists for biomass to make this extra handling worthwhile. Therefore, FFSB partners will continue promoting woody biomass heat and energy.

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